(Hemi-Sync® Journal, Vol. XIV, No. 3, Summer 1996)

An Empirical Investigation Into the Effect of Beta Frequency Binaural-beat Audio Signals on Four Measures of Human Memory

By Richard Cauley Kennerly

[NOTE: This is the complete paper, a portion of which was published in the Summer 1996 Hemi-Sync® Journal.]

Richard Cauley Kennerly is currently the director of clinical services for an adolescent treatment center in metropolitan Atlanta, Georgia. He will begin doctoral studies this Jail in behavioral medicine. Rick has a keen interest in effective nondrug therapies, neuronal regulation, means oj accessing Jidl human potential, and "in general, everything under the sun." His research was a direct outgrowth oj his insatiable thirst for knowledge. After what he describes as a lifetime of academic struggle, Rick discovered that a combination of nutritional supplementation and binaural beat signals could offset his learning disabilities. Learning finally became a pleasure. This thesis arose from his personal success with and interest in binaural beat signals.

ABSTRACT

Beta frequency binaural-beat audio signals were utilized to investigate facilitation of human performance on two memory tasks and two memory related tasks. Subjects were 50 college students randomly assigned with a double-blind methodology to the control or experimental groups. The control group listened to instrumental music. The experimental group listened to the same music with binaural-beat audio signals bedded under the music. The four dependent variables used were a 25 item word list recall test, a 25 item word list recall/recognition test, and from the WAIS-R the digit symbol and digit span subtests. The experimental group displayed statistically significant ($p>.05$) increases in mean scores with the word list recall test, the digit symbol subtest, and the digit span subtest. No statistically significant increases in the experimental mean over the control mean were noted in the word list recognition/recall subtest. The results indicate that beta frequency binaural-beat audio signals are an effective method for facilitating simple free recall memory, ability to attend, and the ability to persevere at routine motor tasks.

PREFACE

This thesis is the culmination of a long personal struggle with the educational system. I have always loved questioning and learning. Yet before graduate school I never enjoyed, or did well in school. I have spent a lifetime on the edge of academic failure where every mediocre grade was a struggle. As a child, adults told me that I was smart and that there was no reason I shouldn't be able to make excellent grades. The unspoken judgement being that I just didn't want to, that there was something wrong with me or worse, that I just didn't try hard enough. I know I frustrated many people, yet I was the most frustrated one of all.

As an adult I worked my way through college, and graduated out of luck and shear persistence. If I failed a class, I took it over until I made the grade I needed. In graduate school I knew I would need a new strategy, since I could no longer take classes over with the new grade replacing the old. I could not afford to work so hard for such mediocre results. I was still very frustrated, and I turned that frustration into a search for answers.

To my joy, I found a combination of dimethylaminoethanol (DMAE), a nutrient found in seafood, and binaural-beat signals worked well to offset my learning disabilities.

What had been an academic Sisyphean struggle became a genuine pleasure. The effect was one of personal transformation and excellent grades. I felt as though I had been set free from a life long prison.

The thesis you now hold arises out of my personal success with, and interest in, binaural-beat signals.

This thesis is dedicated to Elisabeth Schumacher, my mother. Without her unfailing love and devotion, none of my life achievements would have been possible. She has believed in me when I didn't believe in myself. She has given me support when I needed it, without regard for herself. She has loved me beyond all reason, and that has sustained me down a long and rocky road.

INTRODUCTION

This study is an empirical inquiry into the facilitation of human memory with the use of beta frequency binaural-beat audio signals (BBS's) under conditions designed to control for confounding variables. Previous studies have not controlled for confounding variables, preventing any definite conclusions on the extent to which BBS's may facilitate memory.

Were the observed results with BBS's in previous research the result of placebo effects, a confounding variable, or the binaural-beat signals? It is not an answerable question until research is done demonstrating the effectiveness of BBS's in facilitating memory under more controlled conditions.

The hypothesis and experimental design of this study are constructed to be able to answer the question of the effectiveness of BBS's in facilitating memory under controlled conditions. Statistically significant results in this study would support earlier non-empirical research which has found BBS's to be useful in facilitating improved academic performance among mainstream and Attention Defict/Hyperactive Disorder (ADHD) populations. The results of the earlier studies, and more tightly controlled studies with other brain wave training techniques, suggest that beta frequency BBS's should significantly facilitate memory.

Hypothesis and Operational Definition of Memory

There were four hypothesis used in this research, each postulating that in a study controlling for

confounding variables the experimental group would display a statistically significant improvement in mean scores over the control group at a .05 or less significance level.

Hypothesis one (H1) postulated a statistically significant higher mean score for the experimental group as measured by a 25 item word list recall test.

Hypothesis two (H2) postulated a statistically significant higher mean score for the experimental group as measured by a 25 item word list recall/recognition test.

Hypothesis three (H3) postulated a statistically significant higher mean score for the experimental group as measured by the WAIS-R digit symbol subtest.

Hypothesis four (H4) postulated a statistically significant higher mean score for the experimental group as measured by the WAIS-R digit span subtest.

The statistically significant improvement in the mean scores of the experimental group over the control group on any of the tests allows one to infer that facilitation of test performance occurred. If there were no confounding variables, this facilitation of test performance can be assumed to be the result of the independent variable.

The free recall word list test and the combined recognition/recall test are the two most memory related tasks out of the four presented and thus the two most relevant to drawing any conclusions about the facilitation of memory. Generally memory can be characterized as “the ability to reproduce or recount information that was experienced at an earlier time” (Domjan & Burkhard, 1982, p. 308).

For the purposes of this study memory was operationally defined as a subject’s ability to reproduce the information presented on a test within the limited time allocated for reproduction of that information.

The Four Dependent Variables

Four tests were administered to each of 50 undergraduates participating in the study to obtain data on the effect of binaural-beat signals on memory. The first test, word list free recall, was a simple free recall memory task given to obtain data on the facilitation of memory with beta-frequency binaural-beat signals.

The second test was a German vocabulary combined recall-recognition test given to obtain data on the facilitation of memory with a more complex associative recognition/recall task.

The third and fourth tests were the digit span and digit symbol subtests of the WAIS-R. These two tests were administered in order to gain clarity on the observations of teachers who have used binaural-beat signals in their classrooms. These teachers have reported increases in grades, student attention, and decreased hyperactivity while using binaural- beat audio signals in their classes (Edrington, 1985). The two WAIS-R subtests were used to determine if binaural-beat audio signals could facilitate the ability to attend and persevere at routine tasks. Facilitation of these two features of

cognitive performance may be in part, or in whole, the underlying factors in the facilitation of memory by binaural-beat signals.

What Are Binaural-Beat Audio Signals?

Binaural-beat audio signals are a specific audio entrainment technique for altering a subject's brain waves. Alteration of a subject's brain wave frequency or amplitude produces changes in the subject's performance level on some cognitive tasks (Hutchinson, 1994). Brain-wave training is the utilization of brain-wave altering equipment (usually biofeedback equipment) to produce durable changes in a subject's brain waves (Peniston, & Kulkosky 1989).

Brain-wave training has been found to yield excellent results in the facilitation of human memory, attention span, and relaxation (Hutchinson, 1994). Furthermore, this research has been demonstrating brain-wave training as an effective intervention in impaired levels of functioning due to ADHD, learning disabilities (LD), physical brain trauma, and psychological trauma (Ochs, 1993).

As a specific technique of brain-wave training, BBS's have not been empirically studied to produce statistically significant data on how comparable they are to other forms of brain-wave training. Such results would lay a more solid groundwork for clinicians and clinician researchers who are using, or interested in using, binaural-beat brain-wave training.

It is hoped that this study will be one of the first bricks in the laying of a solid research foundation for support of clinicians and organizations interested in applied research and application of binaural-beat brain-wave training.

REVIEW OF RELATED LITERATURE

There has been a quiet revolution occurring in the study of human cognitive functioning and its associated brain wave activity. Breakthroughs have been occurring whose application may rival the introduction of drug therapies to psychiatry. This new wave of therapies involves non-drug interventions capable of rapidly healing previously resistant pathologies and improving cognitive performance in normal subjects.

These new interventions have arisen out of ongoing research in Electroencephalo-graphic (EEG) feedback. In the sixties, EEG feedback was used primarily to control stress. However the interest of serious researchers waned as EEG biofeedback was embraced in the popular culture as a cure all and was tainted with a somewhat disreputable air by association with the human potential movement. Clinical interest in biofeedback returned with the decline of popular attention to biofeedback and the publication of controlled studies showing the effectiveness of biofeedback in chemical and psychometric tests with up to three years of follow-up (Ochs, 1993).

As new generations of EEG equipment became available, researchers developed an expanding understanding of brain wave patterns. Associations were found between specific patterns of brain wave activity and pathological, normal, and optimal cognitive performance/states.

Utilizing this information, biofeedback researchers have been training subjects who have frequency patterns associated with various disorders to alter their brain wave patterns to match those associated with normally functioning individuals (Hutchinson, 1994). This technique has been found to be a rapid and effective intervention for many severe and resistant pathologies including, “depression, sleep disorders, seizures, chronic fatigue, headaches, mood swings, anxiety” (Hutchison, 1994, p. 361), alcoholism, (Peniston, & Kulkosky, 1989), addiction, attention deficit hyperactive disorder (ADHD), epilepsy, post-traumatic stress, paralysis and cognitive impairment as a result of a stroke or head injury (Ochs,1993).

On the Million Clinical Multiaxial Inventory (MCMI) brain-wave training (BWT) resulted in significant decreases on the “scales labeled schizoid, avoidant, passive-aggressive, schizotypal, borderline, paranoid, anxiety, somatoform, dysthymia, alcohol abuse, psychotic thinking, psychotic depression, and psychotic delusion” when used with vietnam veterans suffering from post-traumatic stress (Peniston, & Kulkosky, 1990, p. 37).

Possible Mechanisms Underlying Brain-wave Training Triggering of Neurotransmitters

Why should helping individuals retrain their brain wave frequency patterns be so helpful? A suggestion might be found in the work of Patterson and Capel (1983) in Surrey, England. They found that different neurotransmitters were triggered by different frequencies and wave forms. For example, a 10-hertz signal boosts production and turnover rate of serotonin. “Each brain center generates impulses at a specific frequency, based on the predominant neurotransmitters it secretes,” says Dr. Capel. “In other words, the brain’s internal communications system–its language, if you like–is based on frequency…” (Ostrander & Schroeder, 1991, p. 264).

The implications of Capel’s & Patterson’s work is that one can alter the brain’s neurochemistry, and thereby it’s functioning, with modifications of brain wave frequency.

The popular drug Prozac alleviates depression by increasing serotonin levels. The serotonin levels are elevated through the selective chemical inhibition of the brain’s serotonin-reuptake enzymes (Kramer, 1993). The positive effect of Prozac on a depressed subject’s mood and social functioning can be profound, effects which are generated by elevating the subject’s serotonin levels.

According to Patterson and Capel, a similar increase in the level of serotonin in the brain could be achieved through the induction of a 10-hertz signal. Could we alleviate depression and other impairments associated with low serotonin levels as effectively with brain wave training as with Prozac? What about other forms of impaired mental functioning for which we have no effective chemical interventions? According to many researchers we can, and the triggering of the release of beneficial neurotransmitters may be why.

Return of the Brain to Pre-Trauma Neurochemical State

The direct release of desirable neurotransmitters through an increase in amplitude of specific brain wave frequencies might not be the only mode of action for brain-wave training. A somewhat related theory of why helping subjects retrain their EEG patterns could be helpful is postulated by Len Ochs,

a California therapist and researcher. Dr. Ochs speculates that the neurochemical response to trauma may become entrained as a permanent state, limiting normal functioning, and that brain-wave training may allow a return to the pre-trauma neurochemical state.

Dr. Ochs postulates that psychological or physical trauma induces such a high level of neurochemical excitement that a seizure may be imminent. In order to protect itself, the brain responds with inhibitory chemicals. One could visualize it as the neurochemical equivalent of curling up in a ball. In a protective stance, the inhibited brain has lost function, just as person curled up in a ball cannot walk or function normally in their protective posture.

Dr. Ochs postulates that these inhibitory chemicals may linger in the brain for an extended period of time (one supposes for lack of activation of the proper janitorial reuptake enzymes) or, that the brain mechanism responsible for the production of the seizure protecting neurotransmiters does not reset itself to the pre-trauma state, creating a new homeostatic state of impaired functioning.

If brain-wave training resets the neurochemistry to its pre-trauma state, such a mechanism would explain why it is helpful, and why it works with pathologies resistant to other interventions.

EEG Disentrainment Feedback

Dr. Ochs created an EEG biofeedback device which operates directly on the subjects EEG patterns through light and sound drivers. Normally in EEG biofeedback a subject must attend to, and attempt to respond to a signal which provides information about their brain wave frequencies.

Unlike traditional EEG biofeedback, in Dr. Ochs' device there is no need for the subject to be consciously in the loop or attempting to do anything. The overall brain waves respond to and match the frequency and amplitude of the signals delivered via strobe glasses and headphones. The audio and visual stimuli in turn are generated by the overall amplitude and frequency of the EEG. A computer monitors both and allows the clinician to intervene and sweep the frequencies upward or downward.

Dr. Ochs calls his form of biofeedback "EEG disentrainment feedback (E.D.F.)" (Ochs, 1993). The equipment is actually entraining the brainwave frequencies, yet he refers to it as disentrainment feedback. The disentrainment is for the hypothesized intervention of disentraining a protection mechanism gone awry, a locked in state of emergency brain functioning.

Ochs has been having remarkable results with victims of both psychological trauma and physical brain trauma. He has successfully treated victims of closed head injury, stroke, post-traumatic stress, depression, and addiction. Many of these patients had conditions which were very resistant to treatment with other interventions.

If Dr. Ochs hypothesis is true, then the EDF and all other brain wave retraining devices either activate the proper inhibitory enzyme reuptake mechanism, or they disrupt the seizure inhibition responses which have taken over as the day to day standard for neurochemical functioning.

In either case, brain-wave training would be helping because it allows the brain to reset itself to its normal unimpaired state of functioning. The brain-wave training would not be directly repairing what is impaired, but would be enabling the brain to heal itself (Ochs,1993).

The observations and speculations of Ochs, Patterson and Capel provide some insight into why such “physical therapy” for the brain may work. They illustrate why we might be as effective using brain wave training to improve some individual elements of functioning, such as memory, as well as working on broad fields of impaired functioning such as depression, head injury, addiction, ADHD, ect..

The Peniston Protocol

Perhaps the most famous research to date using EEG biofeedback training has been the work of Peniston and Kulkosky for their procedure, the Penniston protocol. Peniston and Kulkosky used alpha-theta brain-wave training to increase the amount and amplitude of the subjects alpha and theta brain waves.

Dr. Eugene Peniston and Dr. Paul Kulkosky randomly assigned alcoholics to a control group which received conventional medical treatment (Minnesota Model (12 Step)), and an experimental group for which the only interventions were fifteen twenty minute sessions of Alpha-Theta brain wave training. They also included in the study a second control group of non-alcoholics. The results sent a shockwave through every segment of the alcohol treatment community aware of the study (Hutchison, 1994).

The control group, who received traditional medical treatment, demonstrated an 80 percent relapse rate during the thirteen month post treatment follow-up period. The experimental group, who received 15 twenty minute brain- wave training (BWT) sessions (and no other treatment) demonstrated only a 20 percent relapse rate during the same follow-up period. “Depression, as indexed by Becks’s Depression Inventory, was significantly reduced to control (nonalcoholic) level after BWT” (Peniston, & Kulkosky, 1989, p. 276). The alcoholic control group did not demonstrate any significant change in depression as measured by Beck’s Depression Inventory.

Lack of Success with Standard Medical Treatment

Only a twenty percent success rate with traditional intervention techniques in the Peniston & Kulkosky study is not an unusual finding on the effectiveness of currently available alcohol treatment.

At the Washington University Department of Psychiatry, John Helzer and colleagues concluded in their study that “Less than 10 percent of those treated specifically for alcoholism survived and were not drinking alcoholically five to eight years after receiving treatment” (Peele, 1989, p. 78).

In a study of the Minnesota Model at Cambridge following up 100 patients across eight years, researchers concluded “there is compelling evidence that the results of our treatment were no better than the natural history of the disease” (Peele, 1989, p. 74).

Peniston and Kulkosky also note that “major outcome studies that have used specific therapeutic interventions such as controlled drinking, abstinence, compulsory AA attendance, and an active follow-up program yielded results after 2 and 8 years that were no better than those of the natural history of the disorder” (Peniston, & Kulkosky, 1989, p. 271).

Advantage of Brain-wave training Over Standard Medical Treatment

If alcoholism does involve impaired brain function, then the above statistics and results would not be surprising. The subjects who received the traditional medical treatment are fighting against there own physiology, whereas those who are receiving the alpha-theta brain-wave training are not.

Beta-endorphine has been linked to internal control mechanisms for eating and ethanol consumption (Peniston, & Kulkosky, 1989). Based upon an existing literature, Peniston and Kulkosky observe, “If Beta-endorphin is elevated in alcoholics, a return to consumption of ethanol calories would be inevitable” (Peniston, & Kulkosky, 1989, p. 276).

Peniston and Kulkosky did find significantly elevated levels of beta-endorphine in the group who received traditional medical treatment. They did not find elevated levels of beta-endorphine in the group who received the brain-wave training.

Just as a painter with no arms must struggle to overcome the limitations of his physiology to pursue what he wants to do, so might an alcoholic need to struggle against his physiology to pursue his own choices for his life. Within the traditional model of treatment, a basic physiological impediment is not being addressed. According to the findings of Peniston & Kulkosky, that basic physiological impediment is being addressed with brain-wave training; a physiological impediment addressed not with drug therapy, but with a non-invasive technique which allows elevated brain chemistry to return to normal values. This is a technique which in essence allows the brain to heal itself.

The implications of the Penniston protocol are not just for the alcoholic, but also for any victim of the class of impaired brain functioning Dr. Ochs discusses. Under his model anyone with impaired neurochemistry (such as elevated beta-endorphine) would receive the same benefit of normalized brain chemistry after the brain-wave training.

EEG Beta Brain-wave training

While the Peniston protocol focuses on Alpha and Theta brain-wave training, other researchers have been looking into the benefits of using brain-wave training for beta frequencies. Beta training is another brain-wave training technique which trains the subjects to increase the amplitude and frequency of their mid-range beta frequencies. Beta training has been found to be an effective tool for treating ADHD and dyslexia (Hutchison, 1994, p. 360) and would seem to be significant particularly in the area of education.

In a controlled study, (Dr. Siegried) Othmer has found that this beta training produces average IQ increases of 23 percent. In cases where the starting IQ value was lower than 100, the average IQ increase was 33 points. Othmer has also found dramatic improvements in visual retention and

auditory memory, and the subjects showed major gains in reading and arithmetic. In a one-year follow-up study, the trainees showed major improvements in self-esteem and concentration and significant improvements in such areas as handwriting, school grades, sleep, irritability, organization, hyperactivity, verbal expression, and headaches…Amazingly the improvements seem to be permanent. (Hutchison, 1994, p. 360-361).

These results warrant further research and beckon for educational application. How many special education classes and special education students could benefit from significant improvements in levels of hyperactivity, irritability, organization, and self-esteem? How many mainstream classes and students would appreciate and benefit from increased auditory memory and visual retention, IQ gains of 23 percent and improvements in verbal expression, reading and arithmetic? Pursuit of beta brain-wave training is clearly warranted for its potential to help students and teachers alike in achieving the goals of quality education.

Barriers of Cost to EEG Brianwave Training

As a tool to facilitate education, Beta training would seem to hold the same promise as alpha-theta training does for alcoholism. Indeed considering the proliferation of destructive drug use among current student populations, alpha-theta training might also be of significant interest in an educational setting. Unfortunately, in an educational environment financial resources limit making available EEG biofeedback brain-wave training to those who could benefit from it.

A major limitation in the application of EEG biofeedback training has been the cost of the equipment and the limited context under which it can be used. It is hard to imagine a classroom where all twenty students are seated with electrodes on their heads and a biofeedback therapist attending to each of them. Even as a lab where the students may go for one period a day, the cost would be prohibitive. The EEG biofeedback equipment can cost between $4,000 and $20,000 (Hutchison, 1994) per machine. Furthermore, EEG biofeedback requires the one on one attention of highly trained personnel. Cost for the therapists and equipment precludes EEG biofeedback training from practical use for most educational settings.

Alternatives to EEG Biofeedback Training

Fortunately, EEG biofeedback training is not the only way to accomplish the EEG training. Audio and visual driving of brain wave frequencies without a feedback loop has been found to be an effective method of performing the same brain-wave training. Currently available to the public for prices ranging from $99 to $350 (Tools for Exploration Vol. V, No. 2 Summer/Fall 1994), are Light and Sound (LS) machines.

These devices use audio and photic driving to alter the users brain waves to the desired frequency and amplitude patterns. Dr. Ochs EEG biofeedback device uses an LS machine as the part of the equipment which drives the alterations in brain-wave frequencies. His device becomes a form of EEG BWT because of the feedback loop through the computer and EEG machine.

An LS machine consist of set of headphones, blackout glasses with small lights placed over each

eye, and a small computer. The computer controls the strobe frequency of the lights, matching them with the frequency of auditory monaural and binaural beats. The LS machines are not only cheaper to purchase than EEG BWT training equipment, but are also cheaper to operate. Unlike EEG biofeedback BWT training they do not require the one on one attention of highly trained personnel (Hutchison, 1994).

Comparable Results with Light and Sound Brain-wave Training and EEG Brain-wave Training

Russell, and Carter, have been using LS brain-wave training with learning disabled (LD), and ADHD children for beta brain-wave training (Russell & Carter, 1990). The purpose of the LS beta training is to increase the amplitude and frequency of beta brain wave activity in the frontal lobes. ADHD has been found to be "linked to abnormally slow brain-wave activity in specific parts of the brain, including the premotor cortex and the superior prefrontal cortex, which are used when people pay attention, or keep still" (Hutchison, 1994, p. 358).

A significant difference in the verbal and performance subtests of the Weschler Intelligence Scale for Children is a diagnostic indicator of possible organicity, ADHD or learning disability (Aiken, 1988). What Dr. Russell and Dr. Howard noted in their LD or ADHD subjects was that whichever subtest was suppressed in the pre-test was significantly raised in the post-test (after the Beta training).

Groups that began with low verbal IQ scores had pronounced gains in verbal IQ, spelling, and arithmetic. Groups that began with high verbal but low performance IQ showed significant gains in non-verbal IQ, reading, spelling and memory…they concluded that the degree of significant improvement in functioning is related to the number of treatment sessions. (Hutchison, 1994, p. 362)

It can be seen that this intervention is normalizing the spread of the WISC subtest scores and apparently following Dr. Ochs hypothesis. The brain-wave training is permitting an individual with impaired functioning to be normalized and enter a state of unimpaired functioning on measures normally associated with organicity.

Russell and Carter suggest that use of LS devices and EEG training "may stimulate either the successful establishing of new neural pathways in the brain or re- establishing of old pathways that have been disrupted" (Hutchison, 1994, p. 363).

The re-establishment of old disrupted neural pathways sounds in essence the same as the primary mode of action for brain wave training hypothesized by Ochs. But if beta, and perhaps all brain-wave training, is doing more than just re-establishing old pathways (if it is actually creating new neural pathways as Russell and Carter suggest) then might it also be of value to expand normal mental capacities?

In the study of ADHD children conducted by Russell and Carter, significant increases in IQ scores were noted as the result of beta training raising the depressed subtest on the WISC. Othmer also found in his beta training biofeedback that ADHD subjects IQ scores rose significantly. These were both populations with impaired functioning whose rise in IQ scores can be viewed as the probable result of gaining an unimpaired level of functioning where before there had been an impaired level of

functioning.

But if beta, and perhaps all brain wave training, is actually creating new neural pathways as a secondary mode of action, and if, as a tertiary mode of action, is stimulating the production of beneficial neurotransmitters as suggested by the work of Dr. Meg Patterson and Dr. Ifor Capel, then it would be reasonable to assume that brain-wave training might actually increase the level of functioning of an unimpaired subject.

Cranial Electrical Stimulation

Research suggestive of just such a hypothesis may be found in the investigation of cranial electrical stimulation (CES). CES is a technique which introduces the desirable frequencies by low level electrical currents applied to the cranium. The medical college at the University of Wisconsin conducted a study on a commercially available CES device, the BT-5. The purpose of the study was to determine if the BT-5 would reduce student anxiety during final exams. The unexpected results were increases in IQ by twenty to thirty points and a conclusion by the researchers that the “BT-5 (CES) stimulation appears to enhance neural efficiency…” (Ostrander & Schroeder, 1991, pp. 265-266).

As with the other forms of brain wave training, CES has a history of research showing significant improvements in individuals with an impaired level of functioning. Like the Peniston protocol, CES brain wave training has had profound beneficial effects on the impaired mental and social functioning of alcoholics and addicts. CES has enabled some addicts and alcoholics to go cold turkey without any withdrawal symptoms, apparently through the stimulation of the production of beneficial endorphins (Ostrander & Schroeder, 1991). CES brain wave training has been found to be effective in the treatment of impaired short term memory in alcoholics. With severe alcoholism, it can take as long as eight years of total abstinence before short term memory returns to its unimpaired level of functioning. With CES brain wave training, it can take as little as five days (Ostrander & Schroeder, 1991).

If neural efficiency is increased, if new neural pathways can be created and if an impaired state of homeostatic functioning can be reset to a fully functional one, then all of these technologies and interventions represent a staggering opportunity to improve the opportunities and quality of life for broad populations of individuals through brain-wave training.

The results that Russell and Carter have obtained with a form of beta brain-wave training which does not involve EEG biofeedback is apparently of the same calibre as Othmer has received with beta brain-wave training involving EEG biofeedback. The demonstrated effectiveness of both approaches validates that one does not need the EEG feedback loop for the brain-wave training to be effective.

This demonstration of comparable results means that the significant potential of brain-wave training does not have to be limited by the fiscal constraints of EEG biofeedback brain-wave training. Despite the lowered cost of the LS brain-wave training devices verses the EEG biofeedback equipment, the LS machines are expensive enough that in an educational setting access may be a significant problem.

There is one other more cost effective method of conducting brain-wave training: binaural- beat audio signals. In the LS machines, the brain waves are altered through the use of light and sound drivers. In binaural-beat audio signal brain-wave training, only sound driving is used to alter brain waves.

Binaural-beat audio signals are the final technology we will discuss and the technology under investigation in this study.

Binaural-Beat Audio Signals

Binaural-beat signals utilize a powerful form of audio driving to alter brain- wave frequencies. In specific forms of intervention, frequencies could be presented to individuals for brain-ave training in essentially the same manner as LS brain wave training.

Binaural-beats signals (BBS's) were first observed by the German scientist H.W. Dove in 1839. In its simplest form BBS's consist of two pure tones of different pitch being presented to each ear. Before the advent of electronic occilators, researchers used tuning forks to produce the tones. Heard in the open air (monaural beats), the sound will wax and wane due to wave interference. A subject can hear these monaural beats with just one ear if need be. Binaural beats occur when the tones are presented separately to each ear. The sound no longer waxes and wanes in the room, but is heard inside the subject's head as a tone synthesized by the brain which does not exist outside of the subject's head (Oster, 1973).

The brain synthesizes the two sounds into a single experienced tone which seems to originate from the center of the subjects head. The synthesizing of the two tones into one experienced tone produces a phenomena known as hemispheric synchronization, where the electrical activity of the two hemispheres of the brain unite into a single synchronous pattern with an overall frequency at the frequency of the difference between the two original tones. If the difference between the two tones matches a particular brain wave state, such as 4-8 Hz (Theta), then the overall brain activity will tend to match that frequency, and hence enter that brain wave state. This phenomena is referred to as the Frequency-Following Response (FFR) and is a powerful form of brai-wnave entrainment (Edrington, & Allen, 1985). The FFR can easily take a subject into Beta, Alpha, Theta, or Delta brain wave states and help them maintain those states.

By using only audio stimulation for brain wave training, the financial access to the benefits of brain-wave training is improved. Equipment is reduced to a simple tape and personal stereo tape player. In the classroom, access is improved by use of open air speakers which prevents the subjects from having to wear any equipment at all and thus does not interfere with the normal structure of a class (Edrington, 1985). But are BBS's as effective as other means of brain-wave training? In an educational setting, if one did want to facilitate memory and learning, how effective would BBS's be?

Existing research has shown that teachers who have used BBS's in their classrooms have reported a decrease in student distractibility and an increase in academic performance (Owens, 1984). A study conducted with an introductory psychology class found significantly higher scores in the experimental group on five out of six tests (Edrington 1983). A study conducted at a government training center found an increase in scores by 30% for Morse code students (Waldkoetter, 1982a) and 75% on

mental-motor skills (Waldkoetter, 1982b) using BBS's in addition to standard teaching procedures. The US Army has also reported positive results in using BBS's, in this case to improve acquisition of a second language (Pawelek, & Larson). Such findings would seem to indicate that in these settings the BBS's are an effective and worthwhile intervention for improving a student's educational level functioning.

Variables in This Study

The Independent variable was the presence of BBS's on the instrumental music tape the experimental group listens to; and the absence of the BBS's on the same instrumental music tape heard by the control group.

Four dependent variables were used to obtain more data on the types of memory facilitated by BBS's. These dependent variables were tests administered to 50 undergraduate students of West Georgia College. The students were randomly assigned with a double-blind methodology to the experimental or control groups. Each student listened to a tape of music (Independent Variable) while being administered a free recall word list test, a novel word recognition/recall test, and two subtests of the WAIS-R (the digit symbol, and digit span). The four tests administered were the Dependent Variables measuring an effect of the Independent Variable on memory.

For the purposes of this study, memory will be defined as "the ability to reproduce or recount information that was experienced at an earlier time" (Domjan, M., & Burkhard, B., 1982, p. 308). Operationally, memory will be defined by the subject's ability to reproduce on each of four subtests the information that was presented to them. The more information a subject is able to reproduce, the higher the subject's score on that test, and the more "memory" that will be considered to have been recorded.

Based upon the existing research, I hypothesized that the experimental group would display a statistically significant improvement in recall over the control group. I made this hypothesis on the basis of the success of previous less rigorous studies on BBS's and on the basis of the success of other forms of beta brain-wave training in the facilitation of human memory and learning.

Purpose and Rationale of This Study

None of the previous research on BBS's have provided adequate controls for other variables, which might account for the improvement in performance on memory and learning tasks. Improvements in memory have been demonstrated with proper controls with other forms of brain-wave training, but this data is lacking for binaural-beat signals. This study is a step toward filling in that gap.

Were the observed results with binaural-beat signals in previous research the result of placebo effects, a confounding variable or the binaural-beat signals? If the BBS's do facilitate memory, do they also facilitate an increased ability to attend as reported by Edrington?

This study is an attempt to demonstrate, in a repeatable manner, the facilitation of memory with the use of BBS's under conditions which attempt to control for confounding variables.

METHOD

Subjects

50 undergraduate students at West Georgia College participated in the study. Some, if not most of the students participated for extra credit, or to meet a course requirement. Five graduate students also participated in the study but the results of their tests were discarded to prevent skewing of the results.

Design

A between-groups design, also known as an independent subject design was used in the study. Subjects were randomly assigned with a double-blind methodology to experimental and control groups. A .05 or less significance level was used to determine whether or not to accept the null hypothesis ($p>.05$) or reject it ($p<=.05$) in favor of the research hypothesis.

The experimental group contained 27 subjects who were presented with a music tape bearing binaural-beat audio signals while performing four different learning tasks.

The control group contained 23 subjects who performed the same four learning tasks as the experimental group. The music tape that the control group listened to did not contain the BBSs but was otherwise identical to the tape the experimental group was presented with.

Latin Squares

In order to counterbalance any effect of practice or fatigue, the order of the four learning tasks was presented on a rotating basis known as “Latin Squares” (Puff, 1982). This was done to insure the even distribution of any carryover effects from one learning task to another.

Subject five was returned to the test order presented for subject one, subject six the same as subject two, ect.. Each group had its own supply of test packets. This was to maintain rotation of the learning tasks within each group to ensure the even distribution across subjects of any carryover effects from one task to another.

Apparatus The Independent Variable

The BBS’s used in the study for beta brain- wave training were provided by The Monroe Institute. There were two tapes, an instrumental music tape for the control group, and the same tape with BBS’s for the experimental group. The presence or absence of the binaural-beat audio signals was the Independent Variable.

The tapes were presented via headphones and stereo tape player at a low volume. The researcher maintained control over the tape volume to prevent any possible confounding of the results by varied volume levels.

The Dependent Variables

The subjects were presented with four different learning tasks: word list recall (appendix B), German vocabulary list recognition/recall (appendix C), and from the WAIS-R (1981) the Digit Span, and Digit Symbol subtests. There are 25 items on both the word list recall, and the German language vocabulary recognition/recall. The scores on the Digit Span and Digit Symbol subtests were scaled by age in accordance with the procedures given in the WAIS-R manual. These four subtests were the dependent variables in the study.

Procedure Informed Consent of Research Subjects

The experimenter presented each subject with a consent form in compliance with the West Georgia Institutional Review Board procedure for research with human subjects. Each subject was instructed to completely read the consent form, including the description of the experiment, before signing and proceeding with their participation in the study.

It was explained to the subjects that the purpose of the experiment was to determine what effect, if any, listening to these tapes at a low volume has on memory tasks. It was explained that the tapes do not contain any subliminal messages, that there will be four separate memory tasks, and that the whole process should take no more than 45 minutes.

The subjects were also informed that if they were interested in the results of the study or their personal scores, those would be available to them after the completion of the study.

Each subject was instructed to ask the experimenter if they had any questions, and if not, to sign the consent form if they were still interested in participating in the study.

Assignment of Subjects and Pre-Test Period

Each subject was then randomly assigned to the control or experimental group by a coin toss. The tapes were labeled K1 and K2 for experimental and control group respectively. A result of heads resulted in the subject being assigned to K1, and a result of tails in their being assigned to K2. At the time of the collection of the data, neither the experimenter nor subject knew which tape was for the experimental group, and which was for the control group.

Once the subject was assigned to a group, the appropriate tape was placed in the tape player, and the subject was asked to listen to the tape for fifteen minutes. The fifteen minute period of listening to the tape was to allow time for the entrainment of the brain waves of the subjects in the experimental group.

While the subject was listening to the tape their name was placed on a list for their professor if they were participating in the study for extra-credit. They were given a subject number which was placed on the front of their test packet. Each test packet was also marked for the sex of the subject, position in latin square rotation, and group.

Presentation of the Four Tests

At the end of the fifteen minutes of listening to the tape, each subject was instructed to continue listening to the tape while being presented with each of the four subtests. Each subject was presented with the learning tasks in as uniform a manner as possible.

The Word List Recall Test

For the word list recall subtest (appendix B), the subject was told, “I would like you to take two minutes and look at the words I am about to give you. When I say “stop” please turn the sheet over. I will provide you with a second sheet of paper on which I would like for you to reproduce as many of the words as you can. After five minutes I will again say “stop,” at which time I would like for you to stop working. If you have any questions I can repeat these instructions, would you like for me to do that, or do you want to proceed?”

If needed the researcher repeated the instructions. When the subject indicated their understanding of the directions the researcher stated, “Ok, let’s proceed.” The researcher then presented the subject with the word list, and timed for three minutes. At the end of three minutes the researcher stated “stop,” and replaced the word list with a blank piece of paper. At the end of five minutes the researcher again stated “stop,” and collected the recalled list from the subject.

The German Vocabulary Recognition/Recall Test

For the German vocabulary recognition/recall list (appendix C), the subject was told “I would like you to take three minutes and look at the words and definitions I am about to give you. When I say “stop” please turn the sheet over. I will provide you with a second sheet of paper on which I would like for you to fill as many definitions of the words as you can. After three minutes I will again say “stop,” at which time I would like for you to stop working. If you have any questions I can repeat these instructions. Would you like for me to do that, or do you want to proceed?” If requested to do so, the researcher repeated the instructions.

When the subject indicated their understanding of the directions the researcher stated, “Ok, let’s proceed.” The researcher then presented the subject with the German vocabulary recognition/recall list and timed for three minutes. At the end of three minutes the researcher stated “stop” and placed a list of the words without definitions in front of the subject while retrieving the original word and definition list. At the end of five minutes the researcher again stated “stop,” and collected the recalled list from the subject.

The Digit Span and Digit Symbol Tests

The experimenter presented the Digit Span and Digit Symbol subtests in accordance with standard test administration procedures for the Wechsler Adult Intelligence Scale, as outlined in the WAIS-R manual.

Scoring of Tests

The Word List Recall and the German vocabulary recognition/recall tests were scored with one point being assigned for each correct answer. These were 25 item tests yielding a possible score of 0 to 25 points for each subject.

The Digit Symbol and Digit Span subtests of the WAIS-R were scored and scaled before being analyzed, in accordance with the procedures outlined in the WAIS-R manual.

Limitations

In an attempt eliminate confounding variables a simple posttest-only design was employed. Each subject was seen in a single interview to be assigned to a group, be exposed to one of the two levels of the independent variable, and finally to have the effect of the independent variable measured. While this design maximized the isolation of the independent variable it did not provide the independent variable an opportunity to exert a cumulative effect upon the dependent variable.

This is an important limitation in this study because of the noted cumulative effect of brain-wave training. Russell and Carter observed “that the degree of significant improvement in functioning is related to the number of treatment sessions” (Hutchinson, 1994, p. 362). Peniston and Kulkosky also note “Time course analysis of the EEG effects of brain-wave training revealed that increases in alpha and theta rhythms occurred gradually across the 15 treatment sessions” (Peniston, & Kulkosky, 1989 p. 276).

The studies which evaluated student performance over a period of weeks or months have had the benefit of the cumulative effect of brain-wave training. The cumulative effect of the binaural-beat audio signals is a part of the brain-wave training process which was not included in the design of this study and may have a significant impact on the strength of the response as measured by the dependent variable.

This study did not provide for repeated exposures to the dependent variable due to limitations in resources. A logical next step might be to conduct this study again with a longitudinal dimension to observe any increase of performance across repeated sessions, and to observe the effect of binaural audio signals on learning as well as memory.

Placebo and suggestion effects were deliberately filtered out with a double-blind design, in order to gain clarity on what role the layered binaural-beat audio signals play in the positive results obtained with binaural-beat audio signals. Some of the positive results of previous studies may have been the result of just such effects, thus the positive results of this study may not be as profound as in previous research.

RESULTS

There were four hypothesis used in this research, each postulating that in a study controlling for confounding variables the experimental group would display a statistically significant improvement in mean scores over the control group at a .05 or less significance level.

Hypothesis one (H1) postulated a statistically significant higher mean score for the experimental group as measured by a 25 item word list recall test. Hypothesis two (H2) postulated a statistically significant higher mean score for the experimental group as measured by a 25 item word list recall/recognition test. Hypothesis three (H3) postulated a statistically significant higher mean score for the experimental group as measured by the WAIS-R digit symbol subtest. Hypothesis four (H4) postulated a statistically significant higher mean score for the experimental group as measured by the WAIS-R digit span subtest.

In reviewing the data the experimental group does display statistically significant higher mean scores on three of the four dependent measures, allowing for the rejection of the null hypothesis for H1, H3, and H4. The obtained data does not allow for the rejection of the null hypothesis with H2. Figures one through four display the mean scores with histograms and significance level.

Word List Free Recall Results

On the Word List Recall subtest, the control group displayed a mean score of 14 correct responses, and the experimental group displayed a mean score of 15.93 correct responses out of a possible 25. When evaluated with a t-test for the statistical significance of the result, the value of t(2.5) is found to fall between a probability of .02 and .01 (df=48). Since this is less than the minimum significance level of .05, the result is considered statistically significant.

Word List Recognition Results

On the Word List Recognition subtest, the control group had a mean score of 12.61 correct responses, and the experimental group had a mean score of 15.04 correct responses out of a possible 25. When evaluated with a t-test for the statistical significance of the result, the value of t(1.76) is found to fall between a probability of .10 and .05 (df=48). Since this is greater than the minimum significance level of .05 the result is not considered statistically significant.

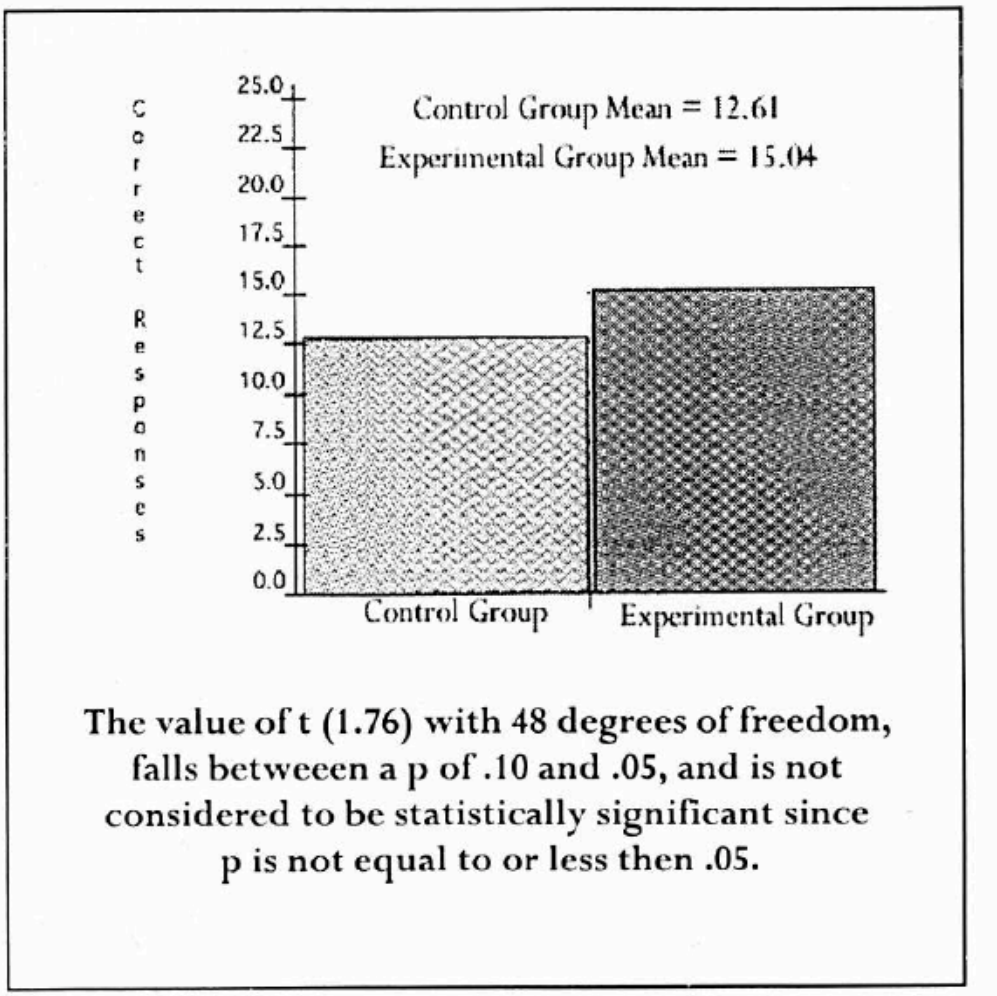

Figure 2. Word List Recognition Mean Scores

Digit Symbol Results

The scaled Digit Symbol subtest displayed a mean score of 9.46 for the control group, and a mean score of 11.44 for the experimental group. When evaluated with a t-test for the statistical significance of the result, the value of t(2.83) was found to be greater than the critical value for a probability of .01 (df=48). Since this is less than the minimum significance level of .05, the result is considered statistically significant.

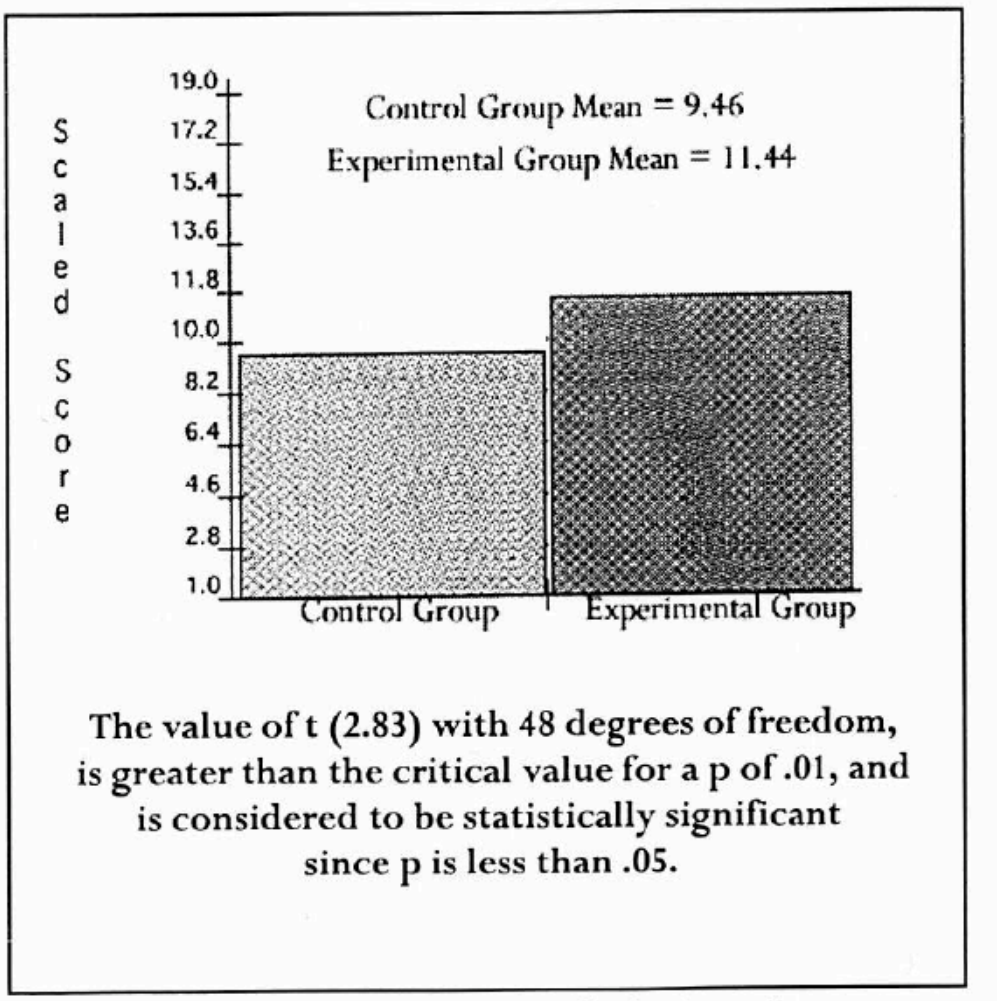

Figure 3. Scaled Digit Symbol Mean Scores

Digit Span Results

The scaled Digit Span subtest displayed a mean score of 7.69 for the control group and 9.85 for the experimental group. When evaluated with a t-test for the statistical significance of the result, the value of t(2.4) was found to fall between a probability of .02 and .01(df=48). Since this is less than the minimum significance level of .05, the result is considered statistically significant.

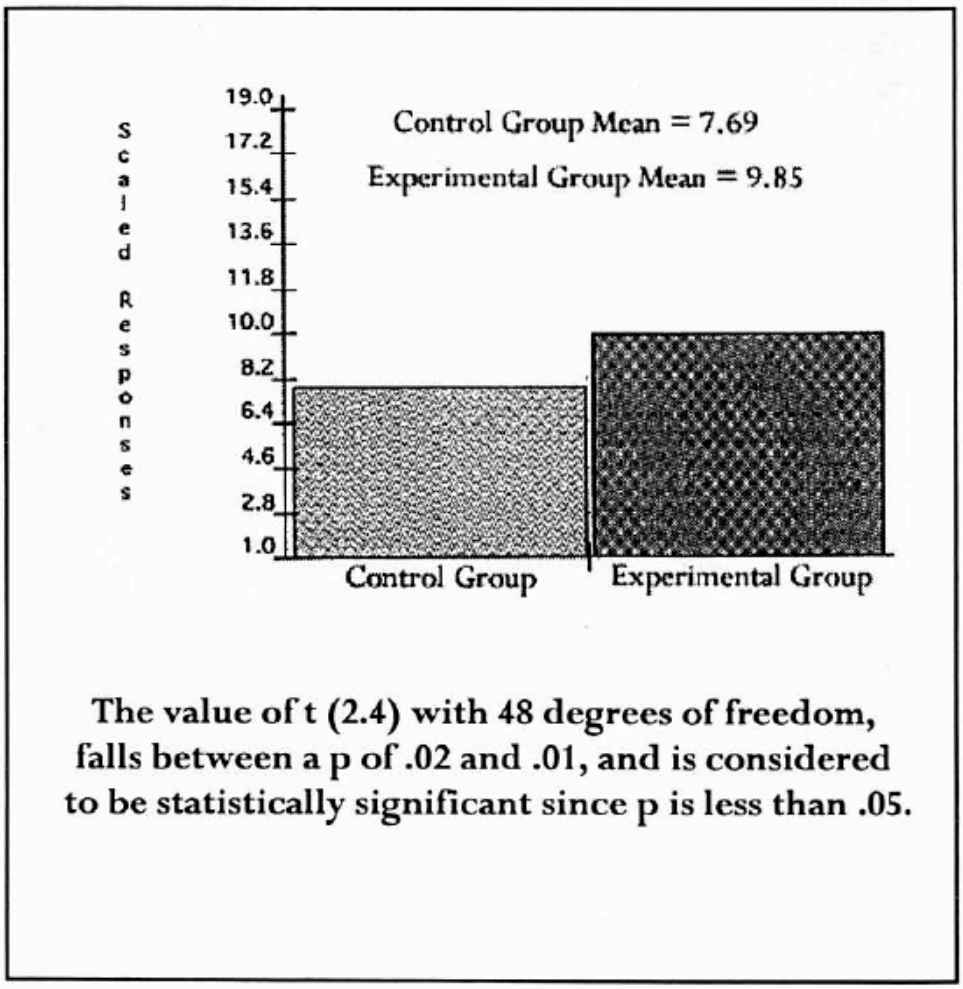

Figure 4. Scaled Digit Span Mean Scores

DISCUSSION

For H1 the Word List Recall test, H3 the Digit Symbol test, and H4 the Digit Span tests, the data does permit the rejection of the null hypothesis in favor of the research hypothesis. For H2 the Word List Recognition test, the data does not allow for the rejection of the null hypothesis.

The data does support binaural-beat audio signals facilitating memory as measured by the word list recall test. The results of the digit span and digit symbol tests support the reports of Edrington, who found a decrease in student hyperactivity and an increased ability to pay attention in class while using BBS's.

It is reasonable to infer, given the current data, that beta-frequency BBS's are helpful for those individuals seeking help in free recall memory, attention and completion of routine tasks.

The Four Dependent Variables

The Word List Recall is a simple free recall test, and thus was considered by the experimenter to be the core dependent variable for examining any facilitation of memory with binaural-beat audio signals. The facilitation of memory as measured by higher mean scores on this test in the experimental group

demonstrate that binaural-beat audio signal beta brain-wave training did facilitate memory.

The German vocabulary recognition list is more of a combined free recall and cued recall task and was also expected to be facilitated by the beta-frequency BBS's. Surprisingly the results for this subtest did not show a statistically significant increase in memory as the other three subtests did.

Since a Latin Squares rotation of the tests was used, this data is not the result of the order of presentation.

The results may mean that the associative memory mechanisms behind remembering the meanings for a novel set of words were not reinforced as strongly as the mechanisms behind the pure recall of a word list.

These results are not expected to be a reflection of previous knowledge of German by some of the subjects. All subjects stated that they did not know German, and the words used were not similar in sound to the English equivalent.

Given that previous work in the comparable task of second language acquisition has reported success with BBS improving performance (Pawelek, & Larson, 1985), the lack of statistically significant mean scores may be an artifact of the single session limitations of this study. As noted in the limitations section, brain-wave training has been shown to increase in effectiveness with repeated sessions.

It would be interesting to see if the data from administering a foreign language vocabulary test would have statistically significant outcomes in a longitudinal study, which would provide for a repeated exposures to beta-frequency BBS brain-wave training.

The Digit Span subtest is not only an indication of an ability to recall and repeat back a series of rote numerical digits, but also of an individuals ability to attend. The increase in Digit Span should be of interest for assisting those populations, such as ADHD, with an impaired ability to maintain their attention on rote memory tasks.

This data supports the anecdotal reports of teachers and other professionals who have reported an increased ability to attend (or a decrease in student distractibility) among their students when using binaural-beat audio signals (Edrington, 1985). The binaural-beat audio signals should, as reported by Edrington, reported, be of use in the classroom to increase the students' ability to attend to the lesson and instructor at hand.

The Digit Symbol test is timed, and the more the subject must look up the meaning of a symbol, the less time he has for filling out the meanings. Heightened memory should facilitate higher scores on this test due to less time spent going back to the list of symbols and their numerical equivalents.

However, the Digit Symbol subtest is not characterized in psychological assessment as a memory test, but as a performance subtest, measuring the subject's ability to persevere at routine tasks.

The increase in performance of the experimental group over the control group at this task may be significant in its implications for assisting those populations who have academic difficulty due to an impaired ability to persevere at routine motor tasks, such as an ADHD child.

Relation of Obtained Results with Previous Research

The results support the ability of BBS's to function as an effective stand alone form of brain-wave training. The research does provide support for the observations of teachers who have reported increased grades and fewer behavioral problems with their students while utilizing binaural-beat audio in the classroom.

The data is able to support the conclusions of previous research that binaural-beat audio signals increase a subject's ability to perform free recall tasks, attend (reduced student distractibility) and persevere at routine tasks (as measured by the Digit Span and Digit Symbol subtests); three important dimensions for success in the classroom.

The beta-frequency BBS brain-wave training did have a positive impact on dimensions of mental performance known to be impaired in ADHD. This opens the possibility that beta frequency BBS's may yield comparable results to the beta frequency brain-wave training conducted with EEG biofeedback and light and sound machines.

The results for the German vocabulary recognition/recall list are not able to support the data on a similar task as reported by Pawelek and Larson in the BBS facilitation of second language acquisition. This may be an artifact of the number of brain-wave training sessions used. It would be interesting to see if the data from administering a foreign language vocabulary test would have statistically significant outcomes in a longitudinal study.

A secondary question of the study was the effect of beta frequency BBS on attention. Could BBS's be used to help ADHD populations? Striking research exists with other forms of brain-wave training (Othmer, Russell, & Carter) facilitating improved performance in ADHD populations. While this study was not designed to answer the question of how effective beta frequency BBS's could be with ADHD subjects, its design was organized to look at one element of ADHD; attention.

In order to gain clarity on the relevance of binaural-beat brain-wave training for use with ADHD populations, the digit span and digit symbol subtests of the WAIS-R were administered. The two WAIS-R subtests were included in the study in order to determine if binaural-beat audio signals could facilitate the ability to attend and persevere at routine motor tasks. Statistically significant results on the free recall word list test, digit span, and digit symbol tests, provide support for the conclusion that beta-frequency BBS's do facilitate improved attention. By inference the BBS form of brain-wave training should be helpful to ADHD subjects. Based upon the success of biofeedback brain- wave training, non-empirical BBS research and this study, further research seems warranted in applied empirical follow-up studies on the facilitation of memory with beta-frequency BBS's among both mainstream and ADHD populations.

Recommendations

It would be rewarding to pursue the effect of binaural-beat audio signals into broader applications. Of particular interest would be the use of binaural-beat audio signals to help ADHD and unimpaired students function at a higher level in mainstream classes.

Another study seems to be in order to properly address the question of whether or not the BBS's can facilitate learning as well as memory. The differentiation being that learning refers to "enduring effects of prior experience" (Domjan, & Burkhard, 1982, p. 309) and memory may be a short lived effect of prior experience. An empirical longitudinal investigation of BBS brain-wave training on learning would clarify the applicability of the BBS brain-wave training technology toward learning in normal and ADHD populations.

Due to the unexpected lack of significant results with the German vocabulary recognition/recall list, a longitudinal study with foreign language vocabulary recognition/recall lists would be of interest. Such a study could determine if this is a task not facilitated by beta frequency BBS brain-wave training, or if it is facilitated only with repeated brain-wave sessions.

Finally it would be of interest to investigate alpha-theta BBS brain-wave training in the treatment of alcoholism and drug abuse. If the results of such a study find comparable benefits to the Peniston protocol, then the social and educational impact would be wide ranging. Access to an effective intervention may be opened up to the alcoholic or addict student. A student may be able to simply go to the school counselor's office to receive effective, lasting treatment for an acute social and educational impairment.

Conclusions

Having found binaural-beat audio signals to be an effective method of facilitating memory on three of the four dependent variables in this study, it may be inferred that they are a viable form of brain-wave training and could provide a portable inexpensive method of assisting students and other individuals in memory tasks. This suggests that the observed results with binaural-beat signals in previous research were the result of the binaural-beat signals and not the result of placebo effects or a confounding variable.

Binaural-beat audio signal brain-wave training could provide a cost effective non- drug alternative to those individuals and educational systems seeking to augment standard techniques. Not only special populations, but mainstream education could benefit from making widely available a form of brain-wave training which makes the learning environment more enjoyable and productive.

It is hoped that this research demonstrated binaural-beat audio signal brain-wave training as a viable alternative to other more expensive and cumbersome methods of brain-wave training. Furthermore, it is hoped that this project will have layed part of the groundwork for more conclusive applied studies with binaural-beat brain-wave training in a variety of student populations and educational environments. Continuing applied research in brain-wave training holds promise to have a profound positive impact on the learning disabled, special education classes and the educational system in general.

REFERENCES

The following materials were consulted for sample, content, and form.

Aiken, L.R., (1988). Psychological Testing and Assessment. Allyn and Bacon, INC.: Newton MA.

Carroll, G.D. (1986). Brain Hemisphere Synchronization and Musical Learning. University of North Carolina at Greensboro. (Available through The Monroe Institute, Rt. 1, Box 175, Faber, VA 22938)

Cozby, P.C. (1989). Methods in Behavioral Research. Mayfield Publishing Company: Mountain View CA.

Domjan, M., & Burkhard, B., (1982). The Principles of Learning and Behavior. Brooks/Cole Publishing Company: Monterey, CA.

Edrington, D. (1983, January). Hypermnesia experiment. Breakthrough. (Available from The Monroe Institute, Rt. 1, Box 175, Faber, VA 22938)

Edrington, D. (1985). A Palliative for Wandering Attention. Tacoma, WA. (Available from The Monroe Institute, Rt. 1, Box 175, Faber, VA 22938)

Edrington, D. (1985). Binaurally Phased Sound in the Classroom. Tacoma WA. (Available from The Monroe Institute, Rt. 1, Box 175, Faber, VA 22938)

Edrington, D., & Allen, C. (1985). 1984-1985 EEG Experiments with Binaurally Phased Audio Stimuli. Tacoma, WA. (Available from The Monroe Institute, Rt. 1, Box 175, Faber, VA 22938)

Hutchison, M. (1994). Mega Brain Power. New York: Hyperion.

Kramer, P.D., (1993). Listening to Prozac: A Psychiatrist Explores Antidepressant Drugs and the Remaking of the Self. New York: Viking.

Ochs, L., (1993). Electroencephalographic Disentrainment Feedback (EDF). Concord, CA. (Electronically published manuscript available from author: Len Ochs, Ph.D., 3490 Silver Spur Court, Concord CA. 94518, or by email at 72040.3433@compuserve.com.)

Ostrander, S., & Schroeder, L. Supermemory: The Revolution. New York: Carroll & Graf Publishers, Inc.

Owens, J.D. (1984). Some reports from teachers using Hemi-Sync. Unpublished manuscript, Tacoma Community College, Tacoma WA.

Pawelek, Y., & Larson, J. (1985). Hemispheric Synchronization and Second Language Acquisition. US Army Educational Services Division, Fort Lewis, WA.

Peele, S. (1989). Diseasing of America Addiction Treatment Out of Control. Boston: Houghton Mifflin Company.

Peniston, E. G., & Kulkosky, P.J. (1989, March/April). Alpha-Theta Brain wave Training and B-Endorphine Levels in Alcoholics. Alcoholism: Clinical and Experimental Research,13, (2), 271-279.

Peniston, E. G., & Kulkosky, P.J. (1990). Alcoholic Personality and Alpha-Theta Brain wave Training. Medical Psychotherapy, 3, 35-37.

Puff, C. R., & Murphy, M.D. (1982). Free Recall: Basic Methodology and Analyses. In Puff, C. R. (Ed.), Handbook of Research Methods in Human Memory and Cognition. (pp. 110-111). New York: Academic Press.

Russell, H.L. & J.L. Carter (1990). Cognitive and Behavioral Changes in Learning Disabled Children Following the Use of Audio- Visual Stimulation: The Trinity Project. Paper presented at the 16th annual meeting of the Biofeedback Society of Texas, Dallas.

Solso, R. L., & Johnson, H. H. (1989). An Introduction to Experimental Design in Psychology, A Case Approach. New York: Harper & Row, Publishers.

Waldkoetter, R. (1982a). The use of audio guided stress reduction to enhance performance. Unpublished manuscript, The Monroe Institute, Professional Division, Rt. 1, Box 175, Faber, VA 22938)

Waldkoetter, R. (1982b). Executive summary. (Unpublished manuscript, The Monroe Institute, Professional Division, Rt. 1, Box 175, Faber, Va 22938)